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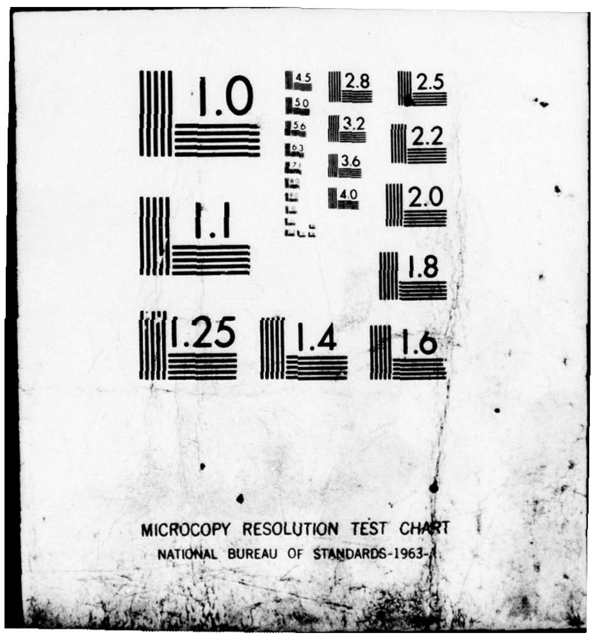
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NRL Memorandum Report 4032

Report of Cyclotron Facility Operations

October 1, 1978 through March 31, 1979

ROLLON O. BONDELID

Cyclotron Applications Branch
Radiation Technology Division

June 26, 1979

NAVAL RESEARCH LABORATORY
Washington, D.C.

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Reactor materials	Linear energy transfer	Positive ion beams

(Continues)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is the sixth in a series of quarterly reports summarizing the use of the Naval Research Laboratory Cyclotron Facility. During the six month period ending March 31, 1979, the cyclotron was used in support of six research programs for a total 930 hours of beam on target. These research programs are summarized in this report together with the details of beam time usage and facility engineering. No major operational problems were encountered.

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H11-01
H01-57
H01-79
H01-94
H01-83
H11-07
H11-08

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Neutron beams
Nuclear reactor
Neutron production
Non-military application
Cancer treatment

CONTENTS

REPORT OF CYCLOTRON FACILITY OPERATIONS
October 1, 1978 through March 31, 1979

I. Introduction

The Naval Research Laboratory Cyclotron Facility began operations as a cost center on October 1, 1977 and completed the first year of such operation on September 30, 1978. For fiscal year 1979 an estimate was made of the projected cost of operating the cyclotron facility and the number of hours users would require the cyclotron beam. These estimates are $273,200 and 2024 hours respectively, leading to a charge of $135 per hour. This report is the sixth in the current series of quarterly reports covering operation of the NRL Cyclotron Facility as a cost center from October 1, 1978 through March 31, 1979.

II. Beam Time Records

A. The Daily Record

Beam time charge accounting is accomplished using a simple method of coding information. At the end of each week the information is recorded in card images and stored on the disc file of the SEL 32/55 data acquisition computer located in the Cyclotron Facility for later recall and summarization. Figure 1 in the first report of this series is a sample of a beam time code sheet. The method of using this form was also described in the first report.

B. Computer Readout

Tables 1 through 4 show the collated data from the beam time card images.

Table 1 shows the beam time use by program and month. Outage is listed as a point of interest. This table is submitted to the NRL budget branch at the end of each month. Proper charges can then be recorded against the using program and credited to the cyclotron cost center.

Table 2 shows the summary by program and particle. The lowest and highest energies for that particle used are also shown.

Table 3 shows the beam time summaries in various ways. Firstly, by program, secondly, by month and thirdly, by particle. Clearly, the table shows that the greatest user has been the MANTA program.

Table 4 is an overall summary of beam time which lists primarily the reasons for unscheduled outages. From this table we see the major problem source continues to be the power supplies of the cyclotron. Outage number 8, "Experimenters Equipment," is included in total beam-on time, but it is not included as cyclotron down time. The item, "Total Hours Available to Date," is the number of hours from 0000 hours October 1 through 2400 hours March 31. The NRL cyclotron schedule had originally been planned for operating two 8-hour shifts per day for six days

Note: Manuscript submitted May 9, 1979.

per week, holidays and scheduled engineering periods excluded. The utilization factor is the total scheduled time divided by this planned schedule.

III. Engineering and Maintenance

A. Cyclotron

An unexpected collapse of the coaxial channel insert temporily shut down the cyclotron for four eight-hour shifts in March. The time frame for making such a repair has increased by about a factor of two since the cyclotron beam particle demand is largely for deuterons. Because the deuteron beam increases radioactive contamination levels, activation of accelerator components have become a greater problem for personnel. Levels of 15 R/hr are now metered where levels of only 5 R/hr were detected 18 months ago. That sharp increase requires greater surveillance by the Radiation Protection Staff, and more time expended on decontamination tasks by those doing the work.

An improved coaxial channel insert, which was previously developed and fabricated in-house, was installed as a replacement. As a result, improvement in subsequent beam extractions has been logged.

Another unscheduled outage of one eight-hour shift occurred when an alarm, annunciating at midnight in the NRL Security Branch, was acknowleged by a guard who immediately phoned the Chief Cyclotron Operator at his home. During the ensuing hour required for his travel time to NRL and additional time for his supervisor to arrive at the scene, approximately 1200 gallons of high purity (18 megohm-cm) liquid was lost from the closed 4000-gallon demineralized H_2O system. It escaped the system via a ruptured seal at the top of the ballast tank sight glass from which it spewed under pressure, even though the water pumps were off. This ruptured seal is at a level of six inches above the water level in the sight glass under normal operating conditions. Manual valves were closed to isolate the ballast tank from the closed system, at which time the automatic air bleeder valves began spouting damp air. A thorough investigation of plumbing circuits throughout the building resulted in finding, in Experimental Room 1, a manual blowdown valve which was open allowing air, at 100 psig, to pass into the closed H_2O system. After closing the air blowdown valve procedures were implemented to purge the water system of air. In addition to the time required for purging, the cartridges in the 1300 gpm, 180 psig, liquid filter and the screen in the coil power supply water circuits had to be removed and replaced.

A spinoff effect of this outage was created when the sewage ejectors became overloaded due to the 1200 gallon torrent of water. As a re-

sult, floor drains backed up and filled the pit housing the main 50,000 liter/second diffusion pump, shorting out its heater. After draining the pit with sump pumps, the defective heater elements were replaced and cyclotron operational vacuum integrity was restored.

Recently, studies initiated in the Cyclotron Applications Branch have generated a need by Branch physicists for automatic/remote beam stop activation. Such a system has been designed, is in the final stages of fabrication, and will be installed in the data acquisition room with redundant controls rack-mounted at various experimental stations throughout the room. This remote beam stop actuating unit has three modes of operation: (1) the manual mode; (2) the automatic mode, which will close a beam stop after a counter has reached its preset value. There is, in addition, a manual override so that the experimenter can interrupt a run, but then restart and continue to the preset value, and (3) the computer-controlled mode (with manual override). Included in the unit is a failsafe circuit which can be used to detect a program interrupt. The unit also has an internal counter and preset valve circuit which can count TTL compatible signals, including integrators on time pulses or a VCO.

IV. Summary of Facility Use

A. MANTA

Eleven new patients were entered into the neutron therapy program during this reporting period. Twenty-seven patients were in various states of treatment. See the previous reports in this series for a further discussion of the neutron therapy program.

A'. MANTA DOSIMETRY

Clinical research continues on whole-body dosimetry for open and wedged fields. These measurements are taken in a Rando-anthropomorphic phantom and in tissue-equivalent liquid phantoms by means of diodes, ion chambers, foil activation and thermoluminescent dosimeters. These four types of dosimeters are used in an attempt to separate whole-body dose into fast-neutron, thermal-neutron and gamma components.

During this period two runs were made on a continuing collaborative experiment with Dr. Richard Miller of Columbia University to compare the relative biological effectiveness of neutrons with x-rays for the induction of oncogenic cell transformations. Measurements were made in conjunction with Professor Eric Hall of Columbia University to compare the oxygen-enhancement ratio (OER) of the MANTA neutron therapy beam, used as a reference standard, with the OER of the neutron therapy beam of the Franklin-McLean Institute of the University of Chicago.

Two one-week runs were made in continuation of an experiment involving mouse tumor systems performed in collaboration with Professor Herman Suit of Massachusetts General Hospital. Each run is a set of five-fraction treatments, one per day for five days. The object is to compare tumor response and normal tissue reactions for neutron treatment, x-ray treatment, and x-ray treatment in conjunction with hypoxic sensitizers or hypobaric oxygen.

B. Radiation Interactions

Dynamic random access memories (RAM) have been observed to develop soft errors caused by the passage of alpha particles through them. We postulated that alpha particles from the $^{28}Si(n,alpha)^{25}Mg$ reaction also should cause upsets. To investigate this effect dynamic RAMs have been irradiated by high energy neutrons while in the operating mode and have been observed to upset from both the "0" and the "1" state. Single upsets in a 16K RAM were observed at 14 MeV neutron fluences of about 10^8 n/cm^2 and the number of upsets is proportional to fluence. The upsets are statistical in nature and are consistent with a single particle event.

The $^{28}Si(n,alpha)^{25}Mg$ reaction has a neutron threshold at $E_n = 2.75$ MeV, but the cross section becomes significant only at neutron energies above 5 MeV. A 14-MeV neutron can create an alpha with energy between 7.8 and 11.0 MeV depending on the alpha direction with respect to the neutron. At 3.6 eV per electron-hole pair, about 3×10^6 such pairs (0.5 picocoulomb) are created along the path of the alpha.

Before irradiation the entire memory chip was filled with a single character, all 0's or all 1's. The irradiation proceeded until a given fluence of neutrons was produced. The memory was then interrogated for upsets, that is, the number of memory locations which had changed state during the radiation was noted.

C. Neutron Damage

A selected set of commercial LED devices was irradiated with 15-MeV median energy neutrons at liquid nitrogen, dry ice and room temperature. A marked difference in degradation of light output was noted as a function of temperature for the same neutron flux. An attempt to correlate these results with electron trapping action is under way.

Si solid state detectors were exposed to the neutron beam to measure directly the spectrum of (n, charged particles). These measurements were made with and without a radiator (polyethelene) in front of the detector to evaluate a suggestion to use Si diodes for neutron dosimetry.

D. Neutron Spectra

Neutron spectra have been measured using time-of-flight techniques for several deuteron and proton beam energies and several targets. The deuteron beams produce high intensity neutron fluxes that are useful for damage studies. The proton beams are used to tailor spectra to simulate various neutron threats.

The electrical interface has been completed that will enable the nuclear ADC deadtimes to be recorded by the scalers. The interface between the scalers and the computer has been modified so that some intermittent timing problems have been eliminated. The subroutines that will be used to control and read the scalers in the data system have been written. It will be possible to start the scalers when data accumulation is started and stop and read the scalers at the end of data accumulation. A separate task has been written that will periodically read the scalers during the data run. Test programs that simulate the data system control and readout of the scalers have been written.

The data system programs that read back secondaries from tape and combine the data arithmetically, so that the results can be displayed, printed and written back on tape were extensively tested in connection with the silicon detector bombardments.

V. Accounting

Estimates made at the beginning of the fiscal year were for a total beam time of 2024 hours in support of the various programs. The total budget required to support this beam time is estimated to be $273,200. On a straight line extrapolation this would lead to 1012 hours of beam time and a budget of $136,600 for this first half. The actual beam time use for this first half was 930 hours which represents a cost transfer of $125,500. The job order status report through 31 March showed total costs of $127,500.

Table 5 shows a list of purchases required for Cyclotron Facility operation. The table is self explanatory.

VI. Conclusion

The NRL Cyclotron Facility continues to operate effectively as a cost center. Costs will match income and the use of the facility will approach that which was predicted at the start of the fiscal year.

Report Assembled by R. Bondelid

Contributors: R. Allas, G. Miller, E. Petersen, P. Shapiro

Table 1

Beam time summary by program and month

CYCLOTRON APPLICATIONS BRANCH SUMMARY OF BEAM TIME
FY-79 MARCH 31, 1979

PROGRAM	MONTH	BEAM TIME	BT COST	OUTAGE
MANTA 66H01-23A	OCTOBER	158.6 HOURS	$ 21411	9.4 HOURS
	NOVEMBER	113.1 HOURS	$ 15269	10.5 HOURS
	DECEMBER	128.6 HOURS	$ 17361	10.3 HOURS
	JANUARY	129.7 HOURS	$ 17510	1.9 HOURS
	FEBRUARY	108.9 HOURS	$ 14702	2.5 HOURS
	MARCH	109.3 HOURS	$ 14756	17.5 HOURS
	SUBTOTAL	748.2 HOURS	$101009	52.1 HOURS
RADIATION INTER. 66H01-57	JANUARY	6.0 HOURS	$ 810	0.0 HOURS
	FEBRUARY	27.0 HOURS	$ 3645	3.0 HOURS
	MARCH	5.5 HOURS	$ 743	9.6 HOURS
	SUBTOTAL	38.5 HOURS	$ 5198	12.6 HOURS
NEUTRON SPECTROM. 66H01-79	NOVEMBER	6.0 HOURS	$ 810	2.0 HOURS
	DECEMBER	14.5 HOURS	$ 1958	0.0 HOURS
	MARCH	10.0 HOURS	$ 1350	0.0 HOURS
	SUBTOTAL	30.5 HOURS	$ 4118	2.0 HOURS
H + HE IN METALS 66H01-83	OCTOBER	8.0 HOURS	$ 1080	0.0 HOURS
WEAPONS MONITORS 66H01-94	OCTOBER	0.5 HOURS	$ 68	0.0 HOURS
	NOVEMBER	2.3 HOURS	$ 311	0.0 HOURS
	DECEMBER	4.2 HOURS	$ 567	0.0 HOURS
	FEBRUARY	4.3 HOURS	$ 581	0.0 HOURS
	SUBTOTAL	11.3 HOURS	$ 1527	0.0 HOURS
NEUTRON DAMAGE 66H11-01	OCTOBER	1.0 HOURS	$ 135	0.0 HOURS
	DECEMBER	16.7 HOURS	$ 2255	0.0 HOURS
	JANUARY	12.2 HOURS	$ 1647	0.0 HOURS
	MARCH	30.1 HOURS	$ 4064	0.0 HOURS
	SUBTOTAL	60.0 HOURS	$ 8101	0.0 HOURS
NEUTRON EFFECTS 66H11-08	OCTOBER	1.0 HOURS	$ 135	0.0 HOURS
	NOVEMBER	4.5 HOURS	$ 608	0.0 HOURS
	JANUARY	27.7 HOURS	$ 3740	0.0 HOURS
	SUBTOTAL	33.2 HOURS	$ 4483	0.0 HOURS
	TOTAL	929.7 HOURS	$125516	66.7 HOURS

Table 2

Beam time summary by program and particle

CYCLOTRON APPLICATIONS BRANCH SUMMARY OF BEAM TIME
FY-79 MARCH 31, 1979

PROGRAM	PARTICLE	BEAM TIME	ENERGY	RANGE-MEV
MANTA 66H01-23A	DEUTERON	748.2 HOURS	35	35
RADIATION INTER. 66H01-57	DEUTERON	38.5 HOURS	16	35
NEUTRON SPECTRUM. 66H01-79	DEUTERON	30.5 HOURS	16	35
H + HE IN METALS 66H01-83	ALPHA	8.0 HOURS	36	36
WEAPONS MONITORS 66H01-94	DEUTERON	11.3 HOURS	16	35
NEUTRON DAMAGE 66H11-01	DEUTERON	60.0 HOURS	22	35
NEUTRON EFFECTS 66H11-08	PROTON	27.7 HOURS	16	18
	DEUTERON	5.5 HOURS	35	35
	SUBTOTAL	33.2 HOURS		
	TOTAL	929.7 HOURS		

Table 3

Beam time totals by program, month and particle

CYCLOTRON APPLICATIONS BRANCH SUMMARY OF BEAM TIME
FY-79 MARCH 31, 1979

PROGRAM	START UP TIME	BEAM ON TARGET	TOTAL TIME	COST	OUTAGE	SCHEDULED TIME	% ON
MANTA	158.4 HOURS	589.8 HOURS	748.2 HOURS	$ 101007	52.1 HOURS	800.3 HOURS	93.5
RADIATION INTER.	7.8 HOURS	30.7 HOURS	38.5 HOURS	$ 5198	12.6 HOURS	51.1 HOURS	75.3
NEUTRON SPECTROM.	4.5 HOURS	26.0 HOURS	30.5 HOURS	$ 4118	2.0 HOURS	32.5 HOURS	93.8
H + HE IN METALS	1.0 HOURS	7.0 HOURS	8.0 HOURS	$ 1080	0.0 HOURS	8.0 HOURS	100.0
WEAPONS MONITORS	2.9 HOURS	8.4 HOURS	11.3 HOURS	$ 1526	0.0 HOURS	11.3 HOURS	100.0
NEUTRON DAMAGE	8.8 HOURS	51.2 HOURS	60.0 HOURS	$ 8160	0.0 HOURS	60.0 HOURS	100.0
NEUTRON EFFECTS	8.0 HOURS	25.2 HOURS	33.2 HOURS	$ 4482	0.0 HOURS	33.2 HOURS	100.0
TOTALS	191.4 HOURS	738.3 HOURS	929.7 HOURS	$ 125511	66.7 HOURS	996.4 HOURS	93.3

MONTH	BEAM TIME	OUTAGE	SCHEDULED TIME	% ON
OCTOBER	169.1 HOURS	9.4 HOURS	178.5 HOURS	94.7
NOVEMBER	125.9 HOURS	12.5 HOURS	138.4 HOURS	91.0
DECEMBER	164.0 HOURS	10.3 HOURS	174.3 HOURS	94.1
JANUARY	175.6 HOURS	1.9 HOURS	177.5 HOURS	98.9
FEBRUARY	140.2 HOURS	5.5 HOURS	145.7 HOURS	96.2
MARCH	154.9 HOURS	27.1 HOURS	182.0 HOURS	85.1
TOTALS	929.7 HOURS	66.7 HOURS	996.4 HOURS	93.3

PARTICLE	BEAM TIME	ENERGY RANGE-MEV		OUTAGE	SCHEDULED TIME	% ON
PROTON	27.7 HOURS	16	18	0.0 HOURS	27.7 HOURS	100.0
DEUTERON	894.0 HOURS	16	35	66.7 HOURS	960.7 HOURS	93.1
ALPHA	8.0 HOURS	36	36	0.0 HOURS	8.0 HOURS	100.0
TOTALS	929.7 HOURS			66.7 HOURS	996.4 HOURS	93.3

Table 4

Beam time summary to show cyclotron performance

CYCLOTRON APPLICATIONS BRANCH SUMMARY OF BEAM TIME
FY-79 MARCH 31, 1979

CYCLOTRON OPERATIVE	HOURS	HOURS
CYCLOTRON START-UP	191.4	
BEAM ON TARGET	738.3	
TOTAL BEAM-ON TIME		929.7
UNSCHEDULED OUTAGE		
1 ION SOURCE	6.7	
2 VACUUM SYSTEM	6.6	
3 DEMINERALIZED WATER	0.7	
4 POWER SUPPLIES	38.2	
5 R. F. SYSTEM	12.3	
6 ELECTRICAL COMPONENTS	2.0	
7 MECHANICAL COMPONENTS	0.2	
8 EXPERIMENTERS EQUIPMENT	1.8	
9 RADIOLOGICAL SAFETY	0.0	
TOTAL OUTAGE	68.5	
TOTAL SCHEDULED TIME		996.4
PERCENT BEAM AVAILABLE (ITEM 8 INCLUDED IN BEAM-ON TIME)		93.3
TOTAL HOURS AVAILABLE TO DATE		4368.0
POSSIBLE SCHEDULED HOURS (2-SHIFTS 6-DAYS PER WEEK)		2400.0
UTILIZATION FACTOR, PERCENT		41.5

Table 5

A listing of purchases required for cyclotron facility operation

CYCLOTRON APPLICATIONS BRANCH SUMMARY OF PURCHASES
FY-79 MARCH 31, 1979

CONTROLS ARE, PROGRAM OPERATIONS MONTH ALL PRICE 0 CATEGORY A ALL

ITEM	COST	PROGRAM	MONTH	CARD	STUB NO.	CATEGORY A
IBM KEYPUNCH	$ 1632	OPERATIONS	OCTOBER	1	13 *	DATA SYSTEM
VYDEC	$ 6391	OPERATIONS	OCTOBER	2	14 *	DATA SYSTEM
SFL SOFTWARE	$ 635	OPERATIONS	OCTOBER	3	15 *	DATA SYSTEM
STAYNEW FILTER	$ 3492	OPERATIONS	OCTOBER	5	25 *	H-2-O SYSTEM
PLASTIC TOP	$ 5	OPERATIONS	OCTOBER	6	37	MATERIALS
DISC CARTRIDGE	$ 192	OPERATIONS	OCTOBER	7	56 *	DATA SYSTEM
GASKET MATERIAL	$ 50	OPERATIONS	OCTOBER	8	57 *	ION SOURCE
XEROX TRANSPARENCIES	$ 64	OPERATIONS	OCTOBER	9	64 *	MATERIALS
DISPATCH CASE	$ 10	OPERATIONS	NOVEMBER	11	77	MATERIALS
DISPATCH CASE	$ 10	OPERATIONS	NOVEMBER	12	78	MATERIALS
DEUTERIUM	$ 255	OPERATIONS	NOVEMBER	14	109 *	MATERIALS
POWER DEVICES	$ 2617	OPERATIONS	NOVEMBER	15	112 *	POWER SUPPLIES
CARTRIDGE REGENERATION	$ 1404	OPERATIONS	DECEMBER	16	120 *	H-2-O SYSTEM
FILTER MEMBRANE	$ 308	OPERATIONS	DECEMBER	17	121 *	H-2-O SYSTEM
CARTRIDGE REGENERATION	$ 1224	OPERATIONS	JANUARY	19	156 *	H-2-O SYSTEM
CUPS	$ 15	OPERATIONS	FEBRUARY	21	221 *	MATERIALS
XEROX TRANSPARENCIES	$ 66	OPERATIONS	FEBRUARY	22	220 *	MATERIALS
ALUMINUM FOIL	$ 10	OPERATIONS	FEBRUARY	23	233 *	MATERIALS
H P ENERGOIL	$ 250	OPERATIONS	FEBRUARY	24	245	VACUUM SYSTEM
CHOPPER	$ 286	OPERATIONS	MARCH	26	253	POWER SUPPLIES
CAMERA REPAIR	$ 40	OPERATIONS	MARCH	27	291	MATERIALS
DEUTERIUM	$ 300	OPERATIONS	MARCH	28	298	ION SOURCE
VACUUM REPAIR KIT	$ 50	OPERATIONS	MARCH	29	299	VACUUM SYSTEM
IONIZATION TUBES	$ 420	OPERATIONS	MARCH	30	297	VACUUM SYSTEM
TOTAL	$ 19806					